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On the cover: The Great Nebula in Orion is a gas cloud excited to incandescence by hot stars in its center. The photograph was made with a 150-in. (3.8-m) telescope. (Copyright by Anglo-Australian Telescope Board, 1981)

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Fermium A chemical element, Fm, atomic number 100, the eleventh element in the actinide series. Fermium does not occur in nature: its discovery and production have been accomplished by artificial nuclear transmutation of lighter elements. Radioactive isotopes of mass number 244–259 have

[illegible]

Spontaneous fission is the major mode of decay for ^{244}Fm , ^{254}Fm , and ^{258}Fm . The longest-lived isotope is ^{257}Fm , which has a half-life of about 100 days. Fermium-258 decays by spontaneous fission with a half-life of 0.38 millisecond. This suggests the existence of an abnormality at this point in the nuclear periodic table. See NUCLEAR CHEMISTRY; NUCLEAR REACTION; TRANSURANIUM ELEMENTS. [G.T.S.]

Ferrimagnetism A specific type of ordering in a system of magnetic moments or the magnetic behavior resulting from such order. In some magnetic materials the magnetic ions in a

In general, there is a net moment, the algebraic sum of the sublattice moments, just as for a normal ferromagnet. However, its variation with temperature rarely exhibits the very simple behavior of the normal ferromagnet. For example, in some materials, as the temperature is raised over a certain range, the magnetization may first decrease to zero and then increase again. Ferrimagnets can be expected, in their bulk properties, measured statically or at low frequencies, to resemble ferromagnets with unusual temperature characteristics. See CURIE TEMPERATURE. [L.R.W.]

There are three important classes of commercial ferrites. One class has the spinel structure, with the general formula $M^{2+}_2Fe_2^{3+}O_4$, where M^{2+} is a divalent metal ion. So-called linear ferrites used in inductors and transformers are made of Mn and Zn (for frequencies up to 1 MHz) and Ni and Zn (for frequencies greater than 1 MHz). MgMn ferrites are used in microwave devices such as isolators and circulators. Until the late 1970s, ferrites with square loop shapes held a dominant position as computer memory-core elements, but these gave way to semiconductors. See COMPUTER STORAGE TECHNOLOGY.

The largest usage of ferrite measured in terms of material weight is in the nonlinear B/H range, and is found in the form of deflecting yokes and flyback transformers for television receivers. The cores for these devices must have high saturation induction B_s along with high maximum permeability μ_m at the knee of the B/H curve to frequencies as high as 100 kHz, the effective flyback frequency used in scanning a television tube. Again, MnZn and NiZn ferrites dominate the use in these devices. See TELEVISION RECEIVER. [G.Y.C.]

Ferroalloy A member of an important group of metallic raw materials required for the steel industry. Ferroalloys are the principal source of such additions as silicon and manganese which are required for even the simplest plain-carbon steels; and chromium, vanadium, tungsten, titanium, and molybdenum, which are used in both low- and high-alloy steels. Ferroalloys are unique in that they are brittle and otherwise unsuited for any service application, but they are important as the most economical source of these elements for use in the manufacture of the engineering alloys. These same elements can also be obtained, at much greater cost in most cases, as essentially pure metals. The ferroalloys contain significant amounts of iron and usually have a lower melting range than the pure metals and are therefore dissolved by the molten steel more readily than the pure metal. In other cases, the other elements in the ferroalloy serve to protect the critical element against oxidation during solution and thereby give higher recoveries. Ferroalloys are used both as deoxidizers and as a specified addition to give particular properties to the steel. See STEEL. [G.D.]

Ferrocene Dicyclopentadienyl iron, $(C_5H_5)_2Fe$, an orange crystalline solid with a melting point of $174^\circ C$ ($343^\circ F$). The compound sublimes at $100^\circ C$ ($212^\circ F$), is diamagnetic, and has a dipole moment of zero. The structure of ferrocene, in which an atom of iron is sandwiched between two parallel cyclopentadiene rings, is shown below.



The most outstanding feature of the chemistry of ferrocene is its aromatic character. The aromaticity of ferrocene is evidenced by the manner in which it behaves toward electrophilic reagents. The molecule undergoes typical Friedel-Crafts acylation to yield either the mono- or diacetylated product. Ferrocene also undergoes other electrophilic substitution reactions typical of a reactive aromatic compound. See AROMATIC; MET-ALLOCENE. [F.D.P.]

Ferroelectrics Crystalline substances which have a permanent spontaneous electric polarization (electric dipole moment per cubic centimeter) that can be reversed by an electric field. In a sense, ferroelectrics are the electrical analog of the ferromagnets, hence the name. The spontaneous polarization is the so-called order parameter of the ferroelectric state. The names Seignette-electrics or Rochelle-electrics, which are also widely used, are derived from the name of the first substance found to have this property, Seignette salt or Rochelle salt. See FERROMAGNETISM.

From a practical standpoint ferroelectrics can be divided into two classes. In ferroelectrics of the first class, spontaneous polarization can occur only along one crystal axis; that is, the ferroelectric axis is already a unique axis when the material is in the paraelectric phase. Typical representatives of this class are Rochelle salt, monobasic potassium phosphate, ammonium sulfate, guanidinium aluminum sulfate hexahydrate, glycine sulfate, colemanite, and thiourea.

In ferroelectrics of the second class, spontaneous polarization can occur along several axes that are equivalent in the

paraelectric phase. The following substances belong to this class: barium(IV) titanate-type (or perovskite-type) ferroelectrics; cadmium niobate; lead niobate; certain alums, such as methyl ammonium alum; and ammonium cadmium sulfate.

From a scientific standpoint, one can distinguish proper ferroelectrics and improper ferroelectrics. In proper ferroelectrics, the structure change at the Curie temperature can be considered a consequence of the spontaneous polarization. In improper ferroelectrics, the spontaneous polarization can be considered a by-product of another structural phase transition. Examples of such systems are gadolinium molybdate and boracites.

The spontaneous polarization can occur in at least two equivalent crystal directions; thus, a ferroelectric crystal consists in general of regions of homogeneous polarization that differ only in the direction of polarization. These regions are called ferroelectric domains. Ferroelectrics of the first class consist of domains with parallel and antiparallel polarization, whereas ferroelectrics of the second class can assume much more complicated domain configurations. The region between two adjacent domains is called a domain wall. Within this wall, the spontaneous polarization changes its direction.

As a rule, the dielectric constant ϵ measured along a ferroelectric axis increases in the paraelectric phase when the Curie temperature is approached. In many ferroelectrics, this increase can be approximated by the Curie-Weiss law. See CURIE-WEISS LAW; DIELECTRIC CONSTANT; DIELECTRICS.

Ferroelectrics can be divided into two groups according to their piezoelectric behavior. The ferroelectrics in the first group are already piezoelectric in the unpolarized phase. Those piezoelectric moduli which relate stresses to polarization along the ferroelectric axis have essentially the same temperature dependence as the dielectric constant along this axis, and hence become very large near the Curie point. The spontaneous polarization gives rise to a large spontaneous piezoelectric strain which is proportional to the spontaneous polarization.

The ferroelectrics in the second group are not piezoelectric when they are in the paraelectric phase. However, the spontaneous polarization lowers the symmetry so that they become piezoelectric in the polarized phase. This piezoelectric activity is often hidden because the piezoelectric effects of the various domains can cancel. However, strong piezoelectric activity of a macroscopic crystal or even of a polycrystalline sample occurs when the domains have been aligned by an electric field. The spontaneous strain is proportional to the square of the spontaneous polarization. See PIEZOELECTRIC CRYSTAL; PIEZOELECTRICITY.

Antiferroelectric crystals are characterized by a phase transition from a state of lower symmetry (generally low-temperature phase) to a state of higher symmetry (generally high-temperature phase). The low-symmetry state can be regarded as a slightly distorted high-symmetry state. It has no permanent electric polarization, in contrast to ferroelectric crystals. The crystal lattice can be regarded as consisting of two interpenetrating sublattices with equal but opposite electric polarization. This state is referred to as the antipolarized state. In a certain sense, an antiferroelectric crystal is the electrical analog of an antiferromagnetic crystal.

The piezoelectric effect of ferroelectrics (and certain antiferroelectrics) finds numerous applications in electromechanical transducers. The large electrooptical effect (birefringence induced by an electric field) is used in light modulators. In certain ferroelectrics, light can induce changes of the refractive indices. These substances can be used for optical information storage and in real-time optical processors. The temperature dependence of the spontaneous polarization corresponds to a strong pyroelectric effect which can be exploited in thermal and infrared sensors. [W.K.]